The effect of isolated core training on selected measures of golf swing performance

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Abstract

Purpose: To quantify the effect of an 8-week isolated core training programme on selected ball and club parameters during the golf swing and also the variability of these measures.

Methods: 36 club-level golfers were randomly assigned to an exercise (n=18) or control (n =18) group. The exercise group participated in an 8-week core training programme which included 8 basic exercises. Both groups continued with their normal activity levels including golf. Baseline and post-intervention measurements included club-head speed, backspin, sidespin, and timed core endurance.

Results: Baseline measures for club-head speed, backspin, sidespin and the core endurance test were 79.9 ± 8.4 mph, 3930 ± 780 rpm, 1410 ± 610 rpm and 91 ± 56 s, and 77.6 ± 8.8 mph, 3740 ± 910 rpm, 1290 ± 730 rpm and 69 ± 55 s, for the intervention and control group, respectively. The effect of our core training, when compared to control, was a likely small improvement in club-head speed (3.6%; 90% confidence limits ±2.7%) and a very likely small improvement in muscular endurance (61%; ±33%). The effect on backspin (5%; ±10%) and sidespin (-6%; ±20%) was unclear. Baseline variability for club-head speed, backspin and sidespin (based on 10 swings per golfer) was 5.7 ± 5.3%, 43 ± 19%, 140 ± 180%, and 6.5 ± 5.3%, 53 ± 53%, 170 ± 130% for the intervention and control group, respectively. The effect of the intervention on within-subject variability was a moderate decrease for club-head speed, a small decrease for backspin and a small increase for sidespin, when compared with control.

Conclusions: The benefits achieved from our isolated core training programme are comparable with those from other studies.

Key Words: golf; core stability; core strength; core stability; sports performance; injury.

Introduction

Paragraph Number 1: The core refers to the musculature of the shoulder stabilisers, trunk and the upper leg muscles (22). A major role of the core musculature is to provide dynamic stiffness for the central joints of the body and particularly the spinal joints. The tension created by coordinated core muscular actions induces controllable stiffness of the spine via axial compression (24) and the ability to perform this is often referred to as core stability (21). It is commonly held that a stable core will increase the efficiency of movement (30). Accordingly, there is often an assumption in the sports sciences that core exercises lead to performance improvements. Consequently, core muscles are the target of many strength and conditioning programmes (12;29).

Paragraph Number 2: During the classic golf swing the shoulder-hip complex can reach over 45 degrees rotation. During the modern swing in which emphasis is placed on creating axial rotations of the upper torso with respect to the pelvis, these trunk rotations can be even higher (10). The amount of relative rotation is strongly correlated with both ball velocity (27) and playing standard (36) and is considered by many as a desirable feature of golf swing kinematics. During this swing, the gluteus maximus has been found to be heavily involved in hip stabilization and the erector spinae muscle group are involved with counteracting gravity (26; 35). The abdominal muscles are also very active during the forward stages of the golf swing (28; 35). Core training, made up of a series of exercises targeting a range of muscles including the abdominals, hip abductors/adductors, hip flexors, lumbar spine extensors, is often advocated for golfers (23). To date, there have been several studies which have demonstrated improved golf swing performance as a result of exercise programmes which comprise both core and swing-specific exercises. However, their experimental designs are such that it is difficult to isolate the benefits of the core exercises. The benefits observed could be due predominantly to the core exercises or, as adversaries of core training would argue, due to the swing-specific nature of the exercises (21). As a case in point, the effect of core training and resisted golf swings on golf swing parameters were quantified and considerable improvements were found (23) but it is not possible to determine whether the benefits were acquired due to the loads on the core or due to the swing-specific movements of the upper limb.

Paragraph Number 3: In a sport that is played by over 25 million people worldwide, lower back pain accounts for 25-76% of all golf-related injuries (11). The biomechanics of the swing is widely considered to be a major source of the problem (10). The large rotations of the trunk relative to the pelvis bring the vertebrae close to their extremes of motion resulting in stretching of the surrounding visco-elastic soft-tissues. While this process is believed to contribute to the power of the swing, it is also suggested to contribute to spinal deterioration (10). The swing also involves considerable lateral tilt which, particularly when combined with lumbar flexion, is suggested to contribute to long-term problems in the intervertebral disks (10). Based on the accumulated load theory (20), it is possible that swing-specific exercises come with a long-term cost and thus reducing the swing-specific component of a training programme may be one strategy to reduce the risk of back problems. A potential alternative, core training, which has formed a component of these previously successful golf training interventions (23), is not without its critics (21) and is not proven to provide performance benefits to golfers (29). The aim of this study is to quantify the effect of an 8-week isolated core training programme on selected ball and club parameters during the golf swing and also the variability, a measure of swing consistency, of these measures.

Methods

Paragraph Number 4: Thirty-six male golfers (180.8 ± 6.8 cm, 89 ± 15 kg, 47 ± 12 years) participated in the study. The participants were members of Dinsdale Spa Golf Club (Darlington, UK) and all held official club handicaps of ranging standards (Table 1). Participants were recruited through the completion of a questionnaire within the professional shop. All participants completed an informed consent form and ethical clearance was granted by the Teesside University Ethics Committee. Participants were randomised 1:1 to the exercise intervention group (n = 18), or to the control group (n = 18). Those assigned to the exercise group completed a medical questionnaire and then completed an 8-week core training exercise programme. Both groups were instructed to continue with their normal levels of physical activity that included playing golf.

Paragraph Number 5: To maximise ecological validity, the testing sessions were conducted in the naturalistic setting of the participants' golf club using a portable launch monitor (Vector Pro Launch Monitor VPR200 (Accusport, Winston-Salem, USA)). The system captures multiple exposures of the ball immediately after impact. The frames are used to calculate the linear and angular components of balls launch velocity and also the tangential distance of the centre of gravity of the club head relative to the point of impact. The software outputs various parameters associated with the golf swing performance. It was chosen to report club-head speed, ball backspin and ball sidespin. The spin rates are calculated from the images. The club-head speed is estimated using a four-step process based on the law of conservation of momentum. Specifically, the tangential component of momentum is calculated from the calculated ball spin rates and known inertial characteristics of the ball. The normal component of momentum of the club-head is derived from the linear momentum of the ball and combined with the tangential components to determine the velocity vector (and therefore speed) of the club head. Although, based on the fundamental laws of physics, there are nonetheless two assumptions being made in the estimates of club-head speed and these are that coefficient of restitution between the ball and club and the inertial characteristics of the club are known. Unfortunately, these parameters are not given and thus, to minimise the effect of these assumptions on the estimates, individuals used the same club for all testing sessions and the same ball was used throughout. The participants performed the golf shots on a level practice mat using their own 5 iron. During each testing session, club-head speed and ball spin rates were collected over 10 shots and the mean of the participants' 10 shots was chosen as the summary measure of performance for each test. Approximately 20 minutes after completion of the swing trials, an isometric flexor endurance (25) was performed. Briefly, this test involves placing the upper body against a purpose-built support at an angle of 60° with respect to the horizontal. The support was then removed and the participant attempted to maintain a static position for as long as possible. Isometric flexor endurance is measured by the time elapsed before the trunk falls below 60°. Furthermore, given the similarity of this test and some of the exercises performed during the intervention, it is expected that changes in performance reflect adherence to the exercise program. In total the participants completed 3 testing sessions, two at baseline (separated by 7 days) and one within 4 days after the end of the exercise intervention (8 weeks later). Performance recorded during the second pre-test trial acted as the pre-test score for each of the participants.

Paragraph Number 6: Reliability of the golf club-head speed, ball backspin and ball sidespin and the endurance test was examined using a test-retest experimental design prior to the intervention. All testing was performed at approximately the same time of day and all 36 participants completed three testing sessions. Reliability was quantified using the test-retest correlation coefficient and the typical error (18). All four performance measures demonstrated good test-retest reliability with test-retest correlation coefficients of 0.84 (90% confidence limits: ±0.09), 0.72 (±0.14), 0.68 (±0.16), and 0.78 (±0.12) for club-head speed, backspin, sidespin, and the endurance test, respectively. The values for test-retest reliability were slightly higher than those found for a driver club in recreational players (23) which is most probably due to different clubs being used. In this study typical error (%) was 4.4% (±1.0%), 12.2% (±2.7%), and 30.3% (±7.2%) for club-head speed, backspin and sidespin, respectively. The reliability of the flexor endurance was slightly less than previously reported (25) with our typical error being 32.8% (±7.8%). The typical error data provide valuable information for the interpretation of performance changes on an individual level.

Paragraph Number 7: A plethora of core strengthening and stability exercises have been reported in the literature. The eight core exercises to be used for this intervention were chosen on the basis of simplicity, avoidance of lateral bending of the vertebral column and not requiring additional equipment. The exercise programme was deliberately dissimilar from the golf swing, but designed to activate similar muscles groups to those involved in the swing. The eight core exercises chosen were; double-leg squat, bent-leg curl-up, superman, supine-bridge, prone-bridge, quadruped, lunge and side-bridge. The first three of which were adapted from previous EMG studies. The double-leg squat was performed with the feet shoulder width apart and with neutral spinal alignment (13). The bent leg curl-up was performed with the arms folded across the chest and head, shoulders and upper back were raised off the floor (1). The superman exercise was performed in a prone position with neutral spine alignment and the arms and legs fully extended and held above the floor (5). These three exercises have been shown to elicit high-levels of muscle activity (i.e. >60%) in the multifidus, external obliques and longissimus (13; 1; 5) and above the threshold for inducing gains in core strength (33) while in the other muscles of the core eliciting levels (10-25% MVIC) for inducing gains in core stability (33). The latter five exercises are described in detail elsewhere (7). The supine-bridge, side-bridge, prone-bridge, quadruped and standing lunge were all performed with the spine in neutral alignment. The side-bridge exercise has been suggested to strengthen the gluteus medius and the abdominal external oblique muscles, and the quadruped arm/lower extremity lift exercise may help strengthen the gluteus maximus muscle. The lunge elicits high levels of activity (>45% maximum voluntary isometric contraction (MVIC)) in the vastus medialis. The side-bridge produces activity greater than 60% MVIC in the external oblique (13) and greater than 45% MVIC in the gluteus medius (7). The quadruped elicits high-levels of activity (>45% MVIC) in the gluteus maximus. The lunge produces EMG levels greater than 45% MVIC in the vastus medialis. All the other exercises produce EMG levels less than 45% MVIC, and are considered to be beneficial for training endurance or stabilization (7). The exercises were performed slowly through the range of motion with a 10 s hold. They are considered to be low-risk in terms of the exerting rapid loads on the visco-elastic soft-tissues of the spine or causing lateral bending. To minimise the learning effects all participants were given a familiarisation session. Over the 8-week intervention period, the eight core exercises were repeated three times a week. Functional progression was incorporated after 4 weeks by adding additional limb movements and lengthening the duration of the holding position from 10 s to 15 s. The additional limb movements were as follows; arms raised during double-leg squat, heel touch during bent leg curl-up, contra-lateral arms and leg raises during superman, leg raises during supine-bridge, hip extension to prone-bridge, contra-lateral arms and leg raises during quadruped, slow rotation of trunk when in lunge position and hip abduction during side-bridge.

Paragraph Number 8: Data are presented as the mean ± SD. Prior to analysis all outcome measures were log transformed and then back transformed to obtain the percent difference, with uncertainty of the estimates expressed as 90% confidence limits (CL), between the post and pre-tests. This is the appropriate method for quantifying changes in athletic performance (17). We used mixed effects linear modelling (IBM SPSS version 21.0) to analyse the effect of the core stability training intervention on our four outcome measures. This method allows for and quantifies (as a SD) individual differences in response to the intervention, which are frequently highly variable. An analysis of covariance (ANCOVA) method was adopted to compare the two groups, with the pre-test score as a covariate to control for chance imbalance in our measures between the control and intervention groups at baseline (34). Effects were evaluated for practical significance by pre-specifying 0.2 between-subject SDs as the smallest worthwhile effect (4). Inference was then based on the disposition of the confidence interval for the mean difference to the smallest worthwhile effect; the probability (percentage chances) that the true population difference between trials was substantially beneficial, harmful (>0.2 SDs) or trivial was calculated as per the magnitude-based inference approach (2). These percentage chances were qualified via probabilistic terms and assigned using the following scale: <0.5%, most unlikely; 0.5–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, most likely (16; 17). Magnitude-based inferences were then categorised as clinical for all four outcome measures. The default probabilities for declaring an effect clinically beneficial are <0.5% (most unlikely) for harm and >25% (possibly) for benefit (16). A clinically unclear effect is therefore possibly beneficial (>25%) with an unacceptable risk of harm (>0.5%) (17). To evaluate the effectiveness of the core stability intervention on the variability of the participants' selected swing parameters, within-subject coefficients of variation (CV, %) were calculated for each performance measure (pre and post). These data were then analysed using the same mixed linear model previously described. In the absence of a known sampling distribution for a difference in SD, 90% confidence limits for the mean differences were constructed using a bias corrected accelerated bootstrapping technique of 2000 samples with replacement from the original data. To interpret the magnitude of a CV, the adjusted between-group differences in CV were doubled and assessed against a scale of 0.2 (small), 0.6 (moderate), and 1.2 (large) of the between-subject SDs of the pre-test for each variable (31; 17). Relations between the participants' performance test scores and golfing handicap were examined using a Pearson's product moment correlation, with 90% confidence limits also presented. The following scale of magnitudes (17) was used to interpret the correlation coefficients: <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; >0.9, nearly perfect. All reliability measures were calculated using a custom-made spreadsheet (18). Inferences were based on uncertainty in standardized magnitudes of effects.

Results

Paragraph Number 9: Descriptive data for both study groups are displayed in Table 1. A large negative correlation was observed between golf handicap and pre-intervention club-head speed ($r = -0.61$; 90%CL ±0.18). A moderate negative correlation was observed between golf handicap and backspin ($r = -0.41$; ±0.20), with a small positive correlation between golf handicap and sidespin ($r = 0.20$; ±0.27). A trivial negative correlation was observed between golf handicap and core endurance test performance ($r = -0.07$; ±0.21).

Paragraph Number 10: The adjusted effect of the core training intervention (Table 2) was a likely small beneficial effect on golf club-head speed, with the SD of the individual responses being 1.7% (±4.3%). The effect on backspin and sidespin was unclear, with the SD of the individual responses being -8.2% (±17%) and -32% (±47%), respectively. There was a very likely small beneficial effect (possibly moderate) of the intervention on endurance test performance. The SD of the individual responses was -17% (±42%). Core training also made the golf swing more consistent (Table 3), as evidenced by a moderate decrease in percent variability of club-head speed and a small decrease in variability of backspin. There was a small increase in variability of sidespin.

Discussion

Paragraph Number 11: Despite core training being fundamental to many exercise programmes, very little is known about its isolated effect on sports performance. The aim of this study was to quantify the effect of an 8-week isolated core training programme on golf club-head speed and ball spin parameters. This is the first study to quantify these effects in golf. We observed a likely small beneficial effect of our exercise intervention on club-head speed. The exercise intervention also had a very likely small beneficial effect on core endurance. A further effect of the exercise intervention was a moderate to small reduction in the variability of the participants' repeated club-head speed and backspin, with a small increase the variability of sidespin. Although the findings apply specifically to golf, it is possible that these benefits could transfer to other sports that require substantial asymmetrical movements of the spine (e.g. tennis, hockey).

Paragraph Number 12: Exercise interventions have previously been shown to increase club-head speed in the golf swing and these improvements in speed range from 0.5-6.3% (6; 8; 23; 32). In this study, the improvement in club-head speed was 3.6%, which is comparable to those above. Furthermore, we observed a large association between golf club-head speed and golfing ability, as determined by the golfers' handicap, lending support to the validity of club-head speed as a measure of golf swing performance. We found unclear effects on other measures of the golfing swing performance, namely backspin and sidespin. However, these measures demonstrated only moderate and small associations with golfing ability. Whilst our exercise intervention was successful in improving core endurance, the translation of this to golf performance may be questionable given the trivial association between performance on this test and golfing handicap.

Paragraph Number 13: We also examined the effect of the exercise intervention on the variability, as determined by the CV of the participant's 10 golf swings, of our performance measures. Post-intervention decreases were observed for the variability of club-head speed, backspin, with an increase in sidespin variability. These results could lend some support for not just a cleaner strike of the ball but also that it is hit with greater consistency. Whilst the coefficients of variation for backspin and sidespin were high suggesting that this variable may not be a stable indicator of physical performance (14), it is the relative change in this variable that is of importance in the present study for determining the effect of our intervention on the consistency of the repeated golf swings. Most coaches would agree that consistency is a desirable feature of the golf swing (19).

Paragraph Number 14: To reiterate, the core exercises used in the study were mostly isometric with the spine in a neutrally aligned orientation. Thus, the exercises are expected to place a lower and more evenly distributed stress on the spinal column than swing-specific exercises. Based on skill acquisition theory the degree of transfer of these training effects is likely to be much lower (21). From this perspective the benefits shown in this study are somewhat unexpected. Specifically, the core training programme is an effective strategy to improve some parameters associated with the golf swing. Unfortunately, the experiment was not designed to establish a causal relationship and thus the benefits could be due to a range of factors (e.g. reduced co-contractions, improvements in neural pathways or strength). Nonetheless, it is suggested that these benefits are achieved with a reduced cost to the spine when compared to swing-specific exercises. Such suggestions are somewhat controversial given rising concerns related to core training and back pain (21) and also findings of a recent meta-analysis (29) which found only minimal performance benefits across a range of sports.

Paragraph Number 15: There are several limitations to our approach in terms of addressing the stated aim, firstly in terms of experimental control and secondly in terms of the interpretative value of the results. With regards to the former, neither the quantity nor quality of the exercises undertaken by the participants were directly monitored or controlled. Golf is an individual pursuit and finding suitable times to hold regular organised exercise sessions was extremely difficult. Training logs were also considered but these are subjective and known to be prone to participant bias (3). In terms of the quality of the exercise, limitations were also present. Specifically, training adaptations are known to occur when the level of muscle activity is between 10-25% maximum voluntary contraction (33) yet the techniques available to quantify muscle activity (i.e. quantify the quality of the exercise) are susceptible to issues of variability.

Overcoming such issues is time-consuming and thus monitoring the quality of the exercises was not practical in this study. As a pragmatic alternative to monitoring the quantity and quality of the exercise, we measured what is considered to be an obvious training adaptation of the exercises that is core endurance. Specifically, the change in core endurance is expected to serve as a valid, albeit indirect, summary measure of the quality and quantity of the exercise being undertaken by the participants. The clear and substantial benefits in terms of the core endurance would indicate that adherence was good. The second limitation was with regard to the interpretative value of the results. It is recognised that the performance measures chosen do not necessarily translate into lower golfing scores, although we did find a large association between the estimates of golf club-head speed and golfing handicap, a direct measure of golfing ability. Club-head speed quantifies the movements at the distal end of the kinetic chain and is thus a summary measure of the biomechanical events (e.g. trunk lateral flexion, wrist flexion speed) leading up to the instant of ball-impact. It is recognised that although this approach simplifies the task of statistical analysis, it also makes it difficult to isolate and discriminate the underlying causes of the changes in the swing in terms of biomechanical parameters. In addition, given the complexities of the biomechanics of the core, it would be naïve to assume that all the exercises included in this intervention have contributed evenly, if at all. Our experiment was not designed to establish a causal relationship, rather to highlight whether or not core training in isolation is worth pursuing in terms of golf swing performance. Thus, taken together there are several limitations and simplifications which reduce the experimental control and restrict the interpretative values of the results. Nonetheless, the experimental design is considered sufficiently robust to enable us to isolate the effects of core training on some measures of performance and thus address the stated aim.

Conclusions

Paragraph Number 16: The results of our study demonstrated a likely small beneficial effect of our practical and safe core training exercise intervention on club-head speed. As far as the authors are aware this is the first study to quantify the effect of an isolated core training programme on performance measures in golf. Furthermore, the exercise intervention also had a very likely small beneficial effect on the golfers' core endurance, as measured by an isometric flexor endurance test. A further effect of our exercise intervention was a reduction in the variability of some measures of golfers' repeated club-head speed and backspin, indicating a more consistent golf swing.

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